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HIGH PULSED CURRENTS FROM PHOTO-FIELD EMITTERS

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Abstract : Different microemitters - single or arrays - with various geometries and kinds of material have been irradiated with pulsed laser beams. These emitters working in photo-field emission regime delivered very high intensity electron bunches. Peak intensities as high as some tens of Amps with less than one ns duration have been obtained with U.V. light. New type of microemitters developed in collaboration with BNL have been tested since last year showing the possibility of obtaining charges above 20 nC with low energy laser pulses, ($\epsilon_i = 100\mu J$). The main parameters affecting the choice of these emitters as quantum yield, photocurrent density, electron pulse length, repetition rate and vacuum system level are here discussed. Good performances obtained with these emitters as well as the absence of cesiation make these microemitters interesting candidates for the new generation of linac injectors as well as for multimegawatt RF sources. At LAL, Orsay efforts have been made since three years to develop such electron sources.

I. INTRODUCTION

Photo-field-emission from arrays of micro emitters has been used in the last years under weak photonic illumination, as for infrared photocathodes in astronomical application. [1]

Due to the photoexcitation associated with the tunneling effect, such photocathodes allowed theoretically and practically an excellent quantum yield, with the unique feature to act without the need of any alkaline deposition on their surface.

Research and developement on new linear colliders need electron sources of high brightness which could deliver intense bunches of picosecond duration.

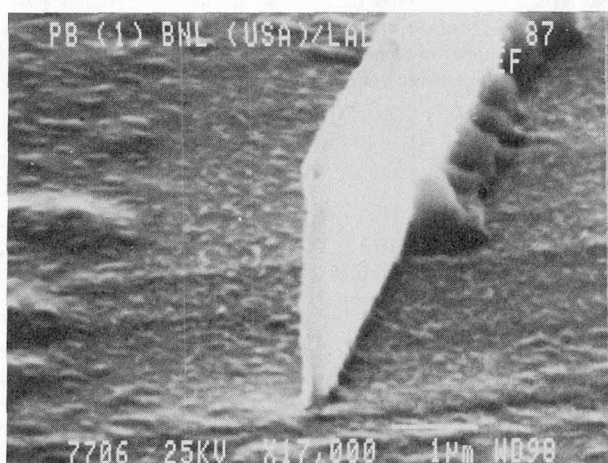
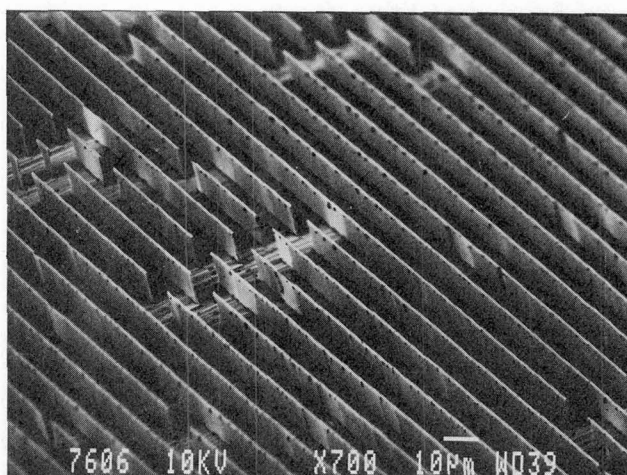
Therefore at LAL, ORSAY we started experimental studies to obtain such pulses by photo-production driven by a pulsed laser on different photo-field emitters.

Some results using Pd Si and WSi microemitters are reported.

II. ARRAYS DESCRIPTION

For our photofield emission experiments we used different samples made of various materials realized by integrated circuit technique on silicon masks. All silicon ridge arrays were diffusion bonded to aluminium planchets. An important parameter for a photo-field emitter is the high local electric field which must be created at the top of them in order to sharpen the surface potential barrier. For that purpose, geometrical design of the array is of particularly importance. Dimensions appear from photographs : Each row of emitters has a thickness of about 0.2 to 0.5 μm , a height of 5 μm and distant from its neighbour of 10 μm .

First, we tested : a ridge pattern which has been sputter coated with 750 Å of tungsten. Then another ridge pattern which is coated with 500 Å of Pd has been tested. For PdSi pattern entire assembly was annealed at 400 ° C for 10 mn in argon to form PdSi layer over ridges. Other samples will be soon tested and especially those of highly n or p doped silicon.

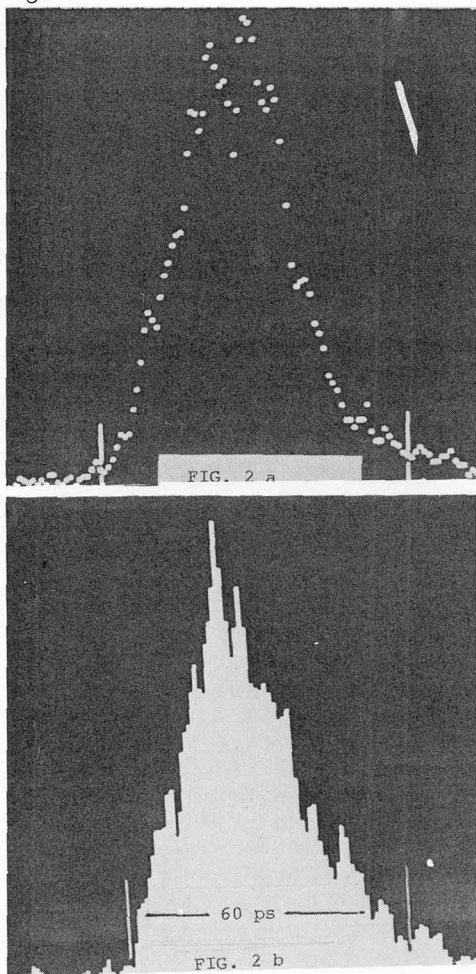


Figures (1a, 1b) show an example of the used microscopical emitters which we have been testing since July 1987. The corresponding photographs were obtained with an electronic scanning microscope (ESM). These photocathodes were provided by the Brookhaven National Laboratory. [2]

XPS analysis on ESM were made before and at the end of each set of experiments.

III. LASER DESCRIPTION

In our tests we used a Nd : YAG laser, which consists of a mode locked Q switched oscillator by saturable absorbent at 10 Hz. It produces a train of picosecond (ps) elementary pulses in different light wavelengths (1ω , 2ω , 3ω) with a chosen frequency modulation from 125 MHz to 3000 MHz using a multiplexer. A single optical amplifier allows the production in visible light with an energy of 8 mJ in the train and 3 mJ in U.V. light in total. The laser oscillator produces a train of 30 ps FWHM pulses. Using a Pockel's cell selector one can choose a simple pulse from the produced burst to illuminate the sample. Figures 2a and 2b show examples of this single pulse, measured with an ARP streak camera in U.V. and green lights.



IV. EXPERIMENTAL RESULTS

The tests were using two different vacuum cells. Produced photocurrents are measured on the cathode holder in the smallest cell (cell n°1 fig.3). This output allows a better knowledge of the emitted photocurrent pulses. In the second cell (cell n°2), produced photoelectrons are collected either on a polarized anode or on a Faraday cup (fig.4).

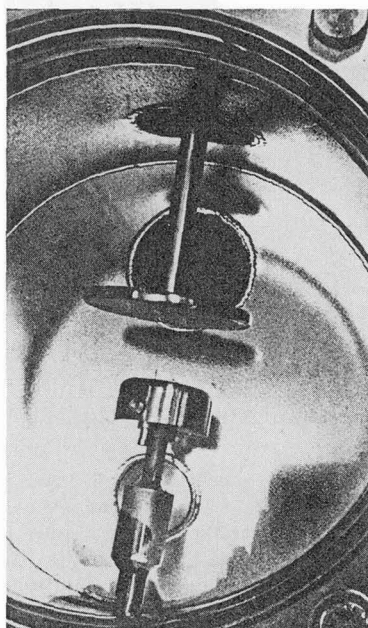


FIG. 3

Transmission light measurements showed that about 10 % of the incident photons are reflected when entering the sapphire window of each cell. Light incidence angle on the photocathode was $\theta \simeq 78^\circ$ in cell n° 1 and variable (roughly) from 0° to 90° in cell n° 2. Tested microcathodes were electrically characterized in field emission regime by Fowler Nordheim plot before their irradiation by the laser beam. Field emission threshold occurred in each cell at different potential values depending of the cathode anode distance. Typically it was for the WSi array of $V = 28$ kV for a cathode anode distance of $\simeq 5$ mm in cell n°1 and of $V \simeq 107$ kV in cell n° 2 for a distance of 20 mm.

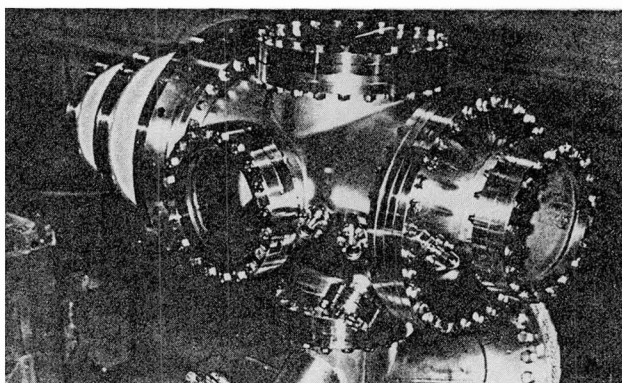


FIG. 4

High local electric field around the upper region of the microemitters ($E_1 \approx 1\text{V}/\text{\AA}$) govern the sharpening of the potential barrier. This result is obtained using a DC high voltage between the array and the anode.

Average photocurrents were measured just below field emission threshold on an ammeter ; then pulsed photocurrents were observed using two different oscilloscopes with bandwidths of 1 and 7 GHz respectively.

IV.1. OBTAINED RESULTS WITH MODERATE HIGH VOLTAGE (cell n°1)

Using WSi sample at $\lambda = 353\text{ nm}$ with a photonic energy $\epsilon_i = 10^{-4}\text{ J} \pm 20\%$, we observed in cell n° 1 the variation of the average photoemission with the D.C. potential (Fig. 5). All potential values were below the observable field emission threshold.

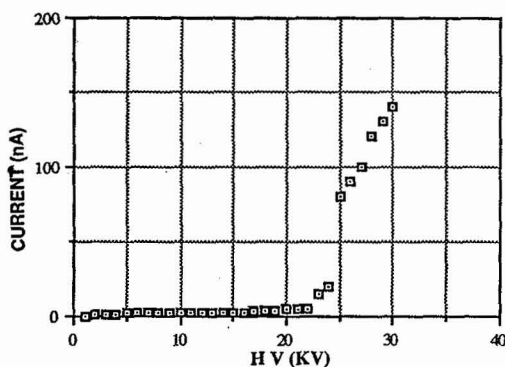


FIG. 5 - Average emission variation with D.C. potential (cell n° 1)

On this figure, we may notice an important enhancement of the photoemission just below the field emission threshold (FET).

In figure 6, variation of the emitted photocurrent vs photonic intensity is represented for a given HV. The important increase of the current may be connected principally to thermic behaviour. Pulse observation on 1 GHz scope showed a thermic tail.

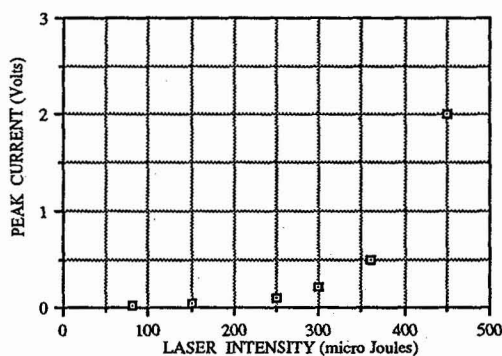


FIG. 6

- Photocurrent variation with photonic intensity (cell n° 1)

Increasing photonic energy to $\epsilon_i = 10^{-3}\text{ J}$ we noticed, just below FET, a strong enhancement of the emission with $4.5\text{ }\mu\text{C}$: the corresponding pulses observed on a 1 GHz scope indicated a peak of about 40 Amp for 100 ns ; the high rate of charges as well as the pulse enlargement indicates an important contribution of thermic effects. After some time, emission rate decreased in this region of the photocathode. Observation on a scanning electronic microscope showed local destruction on about $100\text{ }\mu\text{m}$ by 2 mm (5 % of the total area) (Fig. 7). XPS analysis showed, for this region, that tungsten was removed.

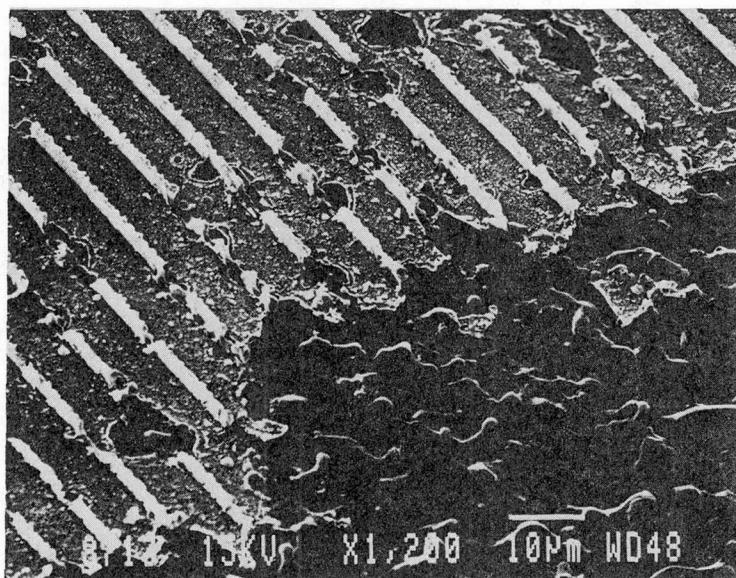


FIG. 7

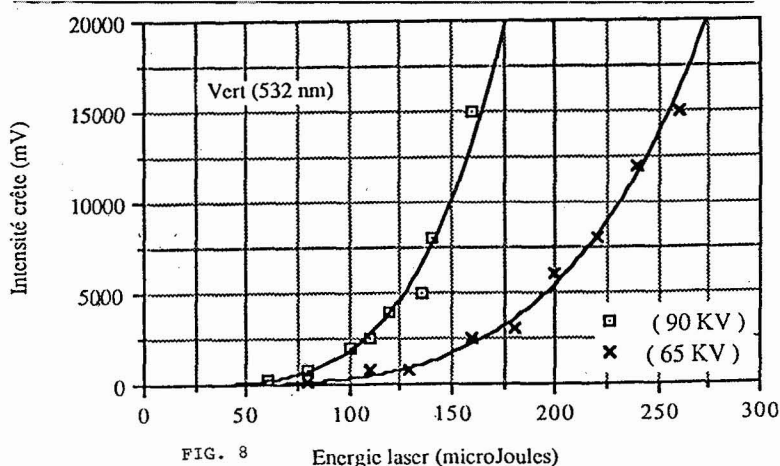


FIG. 8

IV.2.OBTAINED RESULTS WITH MODERATE HIGH VOLTAGE (cell n° 2)

Tests were going on with this photocathode in cell n°2. FET were obtained for different cathode-anode distances. Breakdowns often occurred for potential values above 85 kV and weak photocurrents.

Photocurrent behaviour with incident light power and high voltage has been observed. On fig.8, variation of pulsed photocurrent with optical power (in green wavelength) is showed for two values of the high voltage. Rapid increase of emitted photocurrent may be observed as before.

V. CONCLUSION

These photocathodes presented : high photoemissivity, good reproducibility of the photocurrents with moderate laser energies (less than 2.10^{-4} J), good mechanical stability and good behaviour to a laser light exposure. Such photocathodes could be interesting candidates for laser driven RF guns. Some measurements on these photocathodes will be done in LAL : more precise determination of the photocurrent pulse duration and emittance measurements.

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